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September 28, 2000 HETA 20000400

US National Park Service
ATTN: Joe Alston, Park Superintendent
Glen Canyon National Recreational Area
P.O. Box1507
Page, Arizona 86040

Dear Mr. Alston:

This letter will present preliminary environmental and epidemiologic data regarding fatal and non-fatal carbon monoxide (CO) poisonings that have occurred on Lake Powell, which is in the US National Park Service (USNPS) Glen Canyon National Recreational Area (GLCA). The primary intent of the letter is to bring attention to three severely hazardous situations that must be addressed immediately by appropriate parties. As we will document with following data:

1) The environment in the open space under the swim platform of some houseboats can be lethal under certain circumstances and should not be entered by anyone for any reason as was demonstrated by measurements as high as 30,000 parts of CO per million parts of air (ppm) in that space, and a concurrent oxygen deficiency of 12% in the space.

2) The environment above and around the swim platform may be hazardous as was demonstrated when we measured immediately dangerous to life and health (IDLH for CO is defined as greater than 1,200 ppm) concentrations of CO on the rear deck of a Stardust houseboat during startup of one of the two engines. (Please refer to Attachment 2 for a more complete definition of IDLH.)

3) Employees may be exposed to hazardous concentrations of CO during boat maintenance activities as was evidenced by the short-term, near the IDLH concentrations measured on one maintenance employee.

A more complete data analysis will be presented in a subsequent report.

Background

On August 2, 2000, after an evening meal, occupants of a Stardust multi-owner houseboat activated the rear-exhausting gas-powered generator so that they could operate the air-conditioner and watch videotapes on the on-board television. After the generator had operated for approximately 10-15 minutes, two brothers (ages 8 and 11 years) swam into the cavity under the swim platform of boat. (Please refer to Figures 1 and 2 for diagrams of this space and the swim deck.) Other children swimming with the brothers began screaming when they realized the brothers were in trouble. When adults entered the water to try and save the brothers, they were unable to find them. Emergency medical personnel were also unable to find the boys that evening. The brothers' bodies were pulled from the bottom of the lake (30 feet below the boat) the next morning. These boys died because they were overcome by CO in the space below the swim platform, became unconscious, and sank.

Figure 1. Side View Diagram of Rear Deck, Swim Platform, and Space Beneath the Platform - Generator and Engine Exhaust into the Space

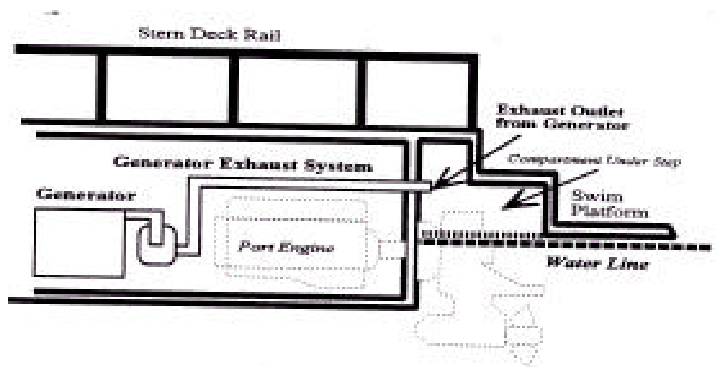
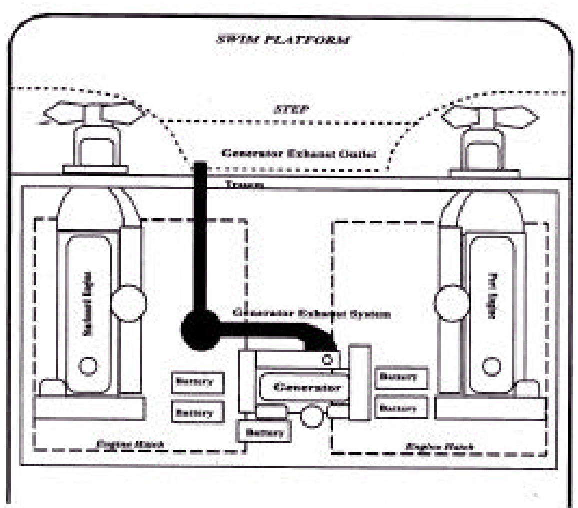


Figure 2. Top View Diagram of Rear Deck, Swim Platform, and Space Beneath the Platform - Generator and Engine Exhaust into the Space



In response to these drownings, the National Park Service, through the US Department of Interior requested assistance from the National Institute for Occupational Safety and Health (NIOSH) and the US Coast Guard to evaluate visitor and employee CO exposures.

An investigative team was assembled (US DOI Industrial Hygienist - Tim Radtke; USNPS Intermountain Region- Lloyd Olson; NIOSH Denver Field Office- Jane McCammon; US Coast Guard - RJ Doubt; USNPS GLCA Superintendent, Park Service, and EMS Staff; USNPS GLCA EMS Medical Director - Dr. Robert Baron; Aramark (the NPS concessionaire) representatives; Utah Parks and Recreation - Ted Woolley). The full group met at Park Headquarters, Page, Arizona, on September 19, 2000.

Results of Record Review

Incident reports and other records were reviewed by DOI and NIOSH prior to the above meeting. For this review, the Park Service assembled the following data from their available records: Number of CO-related fatalities; number of known CO poisonings (non-fatal); number of possible CO poisonings (unknown cause of drowning or symptoms matching CO poisoning); and total number of fatalities on the lake. Park Service Emergency Medical Services (EMS) employees accessed data from the EMS run sheets and incident reports and provided the data for the investigative team. In addition, CO monitoring data collected by USNPS personnel were provided.

According to these records, there have been 9 known boat-related CO poisoning deaths (8 incidents) on the lake since 1994. Some of these incidents involved numerous poisonings in addition to the death/s reported (total of 25 people poisoned in the 8 incidents involving fatalities). Information about the fatalities is listed below:

Houseboat-related Drowning/CO Poisoning Deaths:

Seven occupants (aged 8 to 54 years) of houseboats were overcome by CO and drowned. All houseboat-related deaths occurred when the victim was at the stern (rear) of the boat. Four of these people died within minutes of entering the space under the swim platform. Five deaths occurred when only the generator was running at the time of the fatality. One death occurred when only the boat engines had been operating, and one death occurred when both the generator and engines were operating.

Other Boat-Related CO Poisoning Deaths:

Two deaths occurred in two incidents related to operation of other types of watercraft. Neither of the deaths were drownings, as all affected people were inside the boat when overcome.

In addition, there have been 89 emergency transports of known boat-related CO poisonings (fatal and non-fatal), and 47 transports of possible boat-related CO poisonings since 1991 on Lake Powell. The possible CO poisoning incidents were identified from the database based upon symptoms reported, including loss of consciousness, headache, nausea, seizures, syncope, near drowning of unknown cause, etc. Incident reports related to each of these 136 transports are being collected as of the writing of this letter.

Twenty-five incident reports (52 people - 18 of whom were children aged 3 mos to 16 years) of known non-fatal CO poisonings were available for this preliminary investigation. In these 25 incidents, 25 people experienced loss of consciousness and were resuscitated. Of these, 3 were found unconscious in the water.

During this investigation, a review of hospital records revealed that 2 additional CO poisonings involving loss of consciousness occurred in August 2000. One of these patients was transported to Page Hospital by relatives and thus the report was not found in the EMS incident reports. The second patient was transported by helicopter. No explanation was available about why that case was absent from the EMS records.

During this same time period (1991-2000), there were 128 total deaths in the Glen Canyon Recreational Area. Information about the circumstances of the death were available for 85 of the 128 deaths. 37 of these 85 deaths were noted in the database as drownings (some of which were the CO poisoning drowning incidents).

Sampling Results Related to Three Hazardous Circumstances

USNPS and Aramark staff measured CO concentrations on three houseboats on August 25, 2000. Their report is included with this letter as Attachment 3. The generator exhaust configuration on all three boats was under the rear swim platform. Houseboat generators were not tested under load, but at idle speed with the generators operating for less than 10 minutes. They measured CO concentrations of 1,393, 1,451, and greater than 2,000 ppm at water level below the swim deck of the three boats, each measurement taken approximately 10 minutes after generator activation. CO measurements collected while standing on the swim platforms were 800, 100, and 1156 ppm. During the first test, two of the people conducting the test began to experience symptoms of headache, mild nausea, and weakness.

Methods used by NIOSH and DOI

The environment in the space below the swim deck (see Figures 1 and 2) was characterized using a KAL Equip Model 5000 Four Gas Emissions Analyzer. This analyzer measures CO, carbon dioxide (CO_2), hydrocarbon, and oxygen content of air. All measurements are expressed as percentages. 1% of contaminant is equivalent to 10,000 parts per million (ppm). The emissions analyzer was calibrated prior to use according to the manufacturer's recommendation. Air in the space was characterized under varying circumstances as follows: 1) with the generator operating (at idle and under load); and 2) generator and boat engines operating simultaneously.

Above and below deck airborne concentrations of CO were measured using Toxilog and ToxiUltra Atmospheric Monitors (Biometrics, Inc.) with CO sensors. All Toxilog and ToxiUltra CO monitors were calibrated before and after each use according to the manufacturer's recommendations. These monitors are direct-reading instruments with data logging capabilities. The instruments were operated in the passive diffusion mode, with a one-second sampling interval on the first day, and a 15-second sampling interval on the second day.

Please refer to Attachments 1 and 2 for discussions of health effects of CO exposure and relevant evaluation criteria.

1) Air space below the swim platform: **The data below demonstrate that this space presents an imminent danger and should never be entered by anyone for any reason.**

Boat 1 -

Sampling Date: 9/20/2000
Manufacturer: Lakeview Yachts
Engines: 2 Mercruiser 5.7 liter engines exhausting through the hub
Generator: 12.5 Kw Westerbeke, 4 cylinder, 4 stroke
Exhaust Configuration: Engines and generator exhaust into cavity below the rear deck
Air speed above deck: 475-550 feet per minute
Air speed below deck: 40-80 feet per minute
Ambient temperature: 91 degrees F
Dimensions of space below deck: 4' X 16' X 1.5' - no side vents in the space
Range of CO in the space with generator alone: 0.17 - 0.72% (1,700 - 7,200 ppm)
Range of CO in the space with generator and engines: 0.7 - 2% (7,000 - 20,000 ppm)
Oxygen Deficiency in the Space? Never during this sampling period

Boat 2 -

Sampling Date: 9/20/2000
Manufacturer: Stardust
Engines: 2 Mercruiser 5.0 liter V-8 Bravo engines, hub exhaust
Generator: 15 Kw Westerbeke, 4 cylinder, 4 stroke
Dimensions of space below deck: 4' X 16' X 1.5' - has side vents in the space
Exhaust Configuration: Engines and generator exhaust into the below-deck space
Air speed above deck: 50-200 feet per minute
Air speed below deck: 20 feet per minute
Ambient temperature: 94-110 degrees F
Range of CO in the space with generator alone: 1.2 - 3.0% (12,000 - 30,000 ppm)
Range of CO in the space with just one engine operating: 1.3% (13,000 ppm) during startup
Oxygen Deficiency in the Space? Yes, as low as 13% oxygen in the space with just the generator operating; no measurements during engine operation due to very high CO concentrations that forced stopping the measurements.

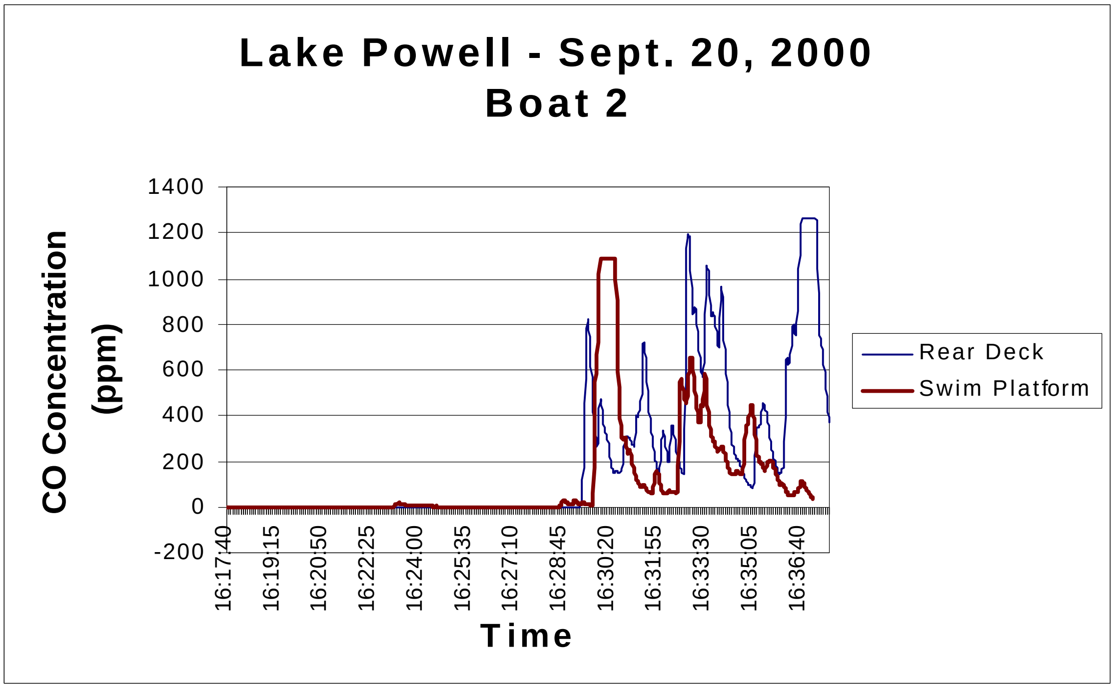
Boat 3 -

Sampling Date: 9/21/2000
Boat Manufacturer: Sumerset
Engines: 2 115 HP Mercury outboards with above deck exhaust enclosure
Generator: 15 Kw Westerbeke, 4 cylinder, 4 stroke
Exhaust Configuration: Generator exhausts to the side of the boat cabin
Air speed above deck: 40-140 feet per minute when in cove during sampling
Air speed below deck: not measured
Ambient temperature: 92 degrees F
Dimensions of space below deck: 16' X 4' X 2'
Range of CO in the space with generator alone: 0 - 0.01% (0 - 100 ppm)
Range of CO in the space with generator and engines: 0.01 - 0.02 % (100 - 200 ppm)
Oxygen Deficiency in the Space? Never during this sampling period

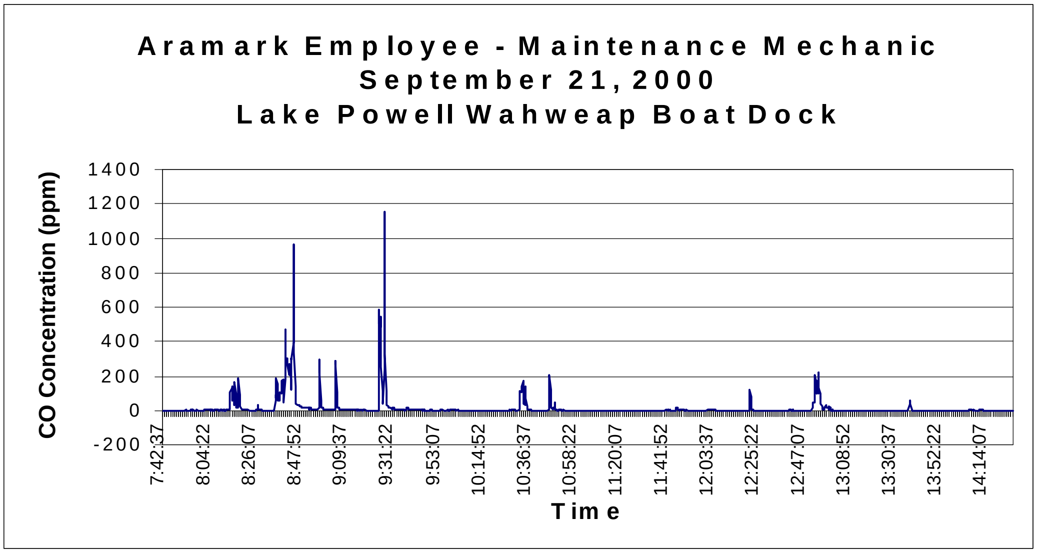
Boat 4 - Boat 3 and Boat 4 were tied together to evaluate the impact of side-exhausting generators in this configuration

Sampling Date: 9/21/2000
Boat Manufacturer: Sumerset
Engines:2 115 HP Mercury outboards with above deck exhaust enclosure
Generator: 15 Kw Westerbeke, 4 cylinder, 4 stroke
Exhaust Configuration: Generator exhausts to the side of the boat hull
Air speed above deck: 150 feet per minute
Air speed below deck: 16' X 4' X 2'
Ambient temperature: 80 degrees F
Dimensions of space below deck:
Range of CO in the space with generator alone: 0 - 0.01% (0 - 100 ppm)
Range of CO in the space with generator and engines: 0.3 - 0.7 % (3,000 - 7,000 ppm)
Oxygen Deficiency in the Space? Never during this sampling period

2) Air space above and around the swim platform: The environment above and around the swim platform may also be hazardous as was demonstrated when we measured IDLH concentrations of CO on the rear deck of Boat 2 when just one of the two engines were operating. The evaluation was discontinued after five minutes due to the excessive concentrations of CO and our concerns about our own exposures. The graph below illustrates these measurements taken on the sitting area of the swim platform on Boat 2. The first and last peaks are flat-topped because the concentration exceeded the measuring capacity of the instrument.



3) Aramark employees: Maintenance employees may also be exposed to hazardous concentrations of CO, as was evidenced by the short-term near or above IDLH concentrations measured on one maintenance employee. The graph below illustrates that one employee experienced CO exposures near or above 1,000 ppm for two periods of short duration, and in excess of the NIOSH recommended ceiling limit (200 ppm) on several occasions through the day. His time-weighted average exposure (TWA) during the period of sampling was 15 ppm. The excessive peak concentrations, although short in duration, indicate a need to control his exposure to exhaust from the boat engines, and to monitor more extensively to better characterize exposures during busier times at the dock.



Discussion and Recommendations

This investigation has identified many issues of concern. We are prioritizing those issues to first address the most severe concerns about which we currently have data.

1) Without doubt, the cavity below the swim platform presents a severe attractive, and sometimes fatal, hazard that must be immediately addressed through design changes and public education. This hazard is present when the generator operates (as is often the case while swimmers are swimming near or under the platform), but also may be present as a result of boat engine operation. All boat owners and renters should be informed of the potentially fatal consequences of entering this area.

2) The owners of boats on which very high CO concentrations have been measured at the swim deck and rear deck of the boat must be immediately informed of the hazard presented by occupancy of these areas. These owners should pursue improved maintenance and/or design of boat engines and platforms to ensure their own safety when engines and/or generators are

operated. Both USNPS GLCA and Aramark staff have expressed willingness to communicate with these owners by transmitting this report to them.

3) Manufacturers of houseboats must be informed of the environmental data that has been collected, and the related design concerns. There are 58 houseboat manufacturers listed on the internet. On September 1, 2000, the National Park Service sent each of these manufacturers a letter informing them of the numerous deaths that may be attributed to CO poisoning from generator and/or engine exhaust. In these letters, the Park Service specifically pointed out that most of the deaths occurred when the victim was either on the back deck or in the water near or under the swim platform. As a followup to the NPS correspondence, NIOSH will forward this letter to those manufacturers, simultaneously requesting responses regarding changes they may have already made in boat design relevant to the potential problem of CO poisoning.

It should be noted that Aramark changed the specifications on boats they order from the supplier for concessionaire rental boats. In 1995, Aramark recognized the hazard related to generator exhaust in the rear and began retrofitting their houseboats to reroute generator exhaust to the rear corner of the boat hull in accordance with ABYC P-1 (American Boat and Yacht Council Standard - Installation of Exhaust Systems for Propulsion and Auxiliary Engines). That year, they also introduced a design specification in purchase orders for new boats requiring that the generator be similarly exhausted. Although none of the fatalities or poisonings reviewed during this investigation occurred on concessionaire boats, side-exhausting of generator exhaust still presents hazards under certain circumstances (a fact recognized by Aramark, and addressed in renter training programs). If two of their boats are aligned and anchored together, exhaust is directed into the neighboring boat and along the channel created between the two boats. During this investigation, IDLH concentrations of CO (greater than 1,000 ppm) were directed along this channel (below deck level) to the water space between the front decks of both boats. This area is a natural place for small children to play because their parents can easily observe them in the shallow water of the shore. Further sampling should be conducted to define hazard zones with boats in this configuration.

4) Aramark should immediately investigate engineering controls to reduce exposures of boat maintenance mechanics. If repairs are conducted outside and at the boat dock (where electric power is easily available), the use of a high volume fan or other air-moving device may be effective in preventing short-term IDLH exposures as measured during this investigation. NIOSH will investigate such controls and provide information as soon as possible.

5) Training about the severity of CO hazards in boating should be developed for Park Service personnel, especially EMS providers, so that symptoms experienced by either employees or other boat operators might be more easily associated with exposures. This training should include both environmental data, as well as information about the number and circumstances of CO poisonings on the lake.

6) The US NPS has launched an awareness campaign to inform boaters on their lake about boat-related CO hazards. This Alert included press releases, flyers distributed to boat and dock-space renters, and verbal information included in the boat check-out training provided for users of

concessionaire rental boats. Training about the specific boat-related CO hazards provided for houseboat renters should be enhanced to include specific information about the circumstances and number of poisonings and deaths. The training (including videotaped training such as that viewed during this evaluation) should include anecdotal information about deaths and near misses, and should specifically target warnings against entering air spaces under the boat (such as the cavity below the swim platform) that may contain a lethal atmosphere.

Future Direction of this Investigation:

<u>At Lake Powell</u>:
NIOSH and DOI will
•Confirm initial environmental data
•Investigate interferences like H_2S
•Monitor Park Service and Aramark employee exposures (CO and noise) during boat operation and maintenance
•Review all 134 incident reports (Known and Possible CO Poisoning Incidents)
•Collect further information about circumstances of deaths in the GLCA Recreational Area
•Further characterize the danger zone around the rear of the boats
•Evaluate what rear design is best/better (grating instead of solid platform, no swim deck, side exhaust, deck top exhaust, etc.)
•Explore alternatives to gas-powered generators (i.e. diesel and/or other fuels, solar energy, etc.)
•Explore exhaust controls such as blowers to more effectively disperse CO.
•Further evaluate the relative contribution of generators versus boat engines.
•Determine the feasibility of the use of catalytic convertors on boat engines.
•Assist with expansion of the Park Service EMS database to include details relevant to CO poisonings.
•Measure expired air CO concentrations to characterize dose, and train Park Service personnel to conduct this type of monitoring.

<u>Other lakes</u>
NIOSH and DOI will:
•Gather case reports from two additional houseboating lakes
•Duplicate occupational and other environmental data collected at Lake Powell (see above)
•Access other databases (NEISS, etc.) to determine feasibility of additional case finding

Thank you for your cooperation with this investigation, and for providing extensive important data related to this serious issue. Please contact either of us if you have any questions about this letter or any aspect of the investigation.

Sincerely,

Jane Brown McCammon, CIH
Director, NIOSH Denver Field Office

Tim Radtke, CIH
US Department of Interior

cc: Dick Powell, USNPS Safety Director
Gary Anderson, Aramark Wahweap
Lloyd Olson, USNPS
Jennifer Fields, Kentucky Commission of Fish and Wildlife
Norm Peterson, Arizona Department of Health
Courtney Casillas, Arizona Public Information Officer
Wayne Ball, Utah Department of Health
Ted Woolley, Utah Parks and Recreation
R.J. Doubt, US Coast Guard
ADM Joyce Johnson, USCG
Mike Kaas, USDOI, Office of Managing Risk and Public Safety

Attachment 1
Health Effects of Exposure to Carbon Monoxide

Carbon monoxide (CO) is a colorless, odorless, tasteless gas produced by incomplete burning of carbon-containing materials such as gasoline or propane fuel. The initial symptoms of CO poisoning may include headache, dizziness, drowsiness, or nausea. Symptoms may advance to vomiting, loss of consciousness, and collapse if prolonged or high exposures are encountered. If the exposure level is high, loss of consciousness may occur without other symptoms. Coma or death may occur if high exposures continue.[1-6] The display of symptoms varies widely from individual to individual, and may occur sooner in susceptible individuals such as young or aged people, people with preexisting lung or heart disease, or those living at high altitudes.

Exposure to CO limits the ability of the blood to carry oxygen to the tissues by binding with the hemoglobin to form carboxyhemoglobin (COHb). Blood has an estimated 210-250 times greater affinity for CO than oxygen, thus the presence of CO in the blood can interfere with oxygen uptake and delivery to the body. Once absorbed into the bloodstream, the half-life of bloodborne CO at sea level and standard pressure is approximately five hours. This means that an initial COHb level of 10% could be expected to drop to 5% in five hours, and then 2.5% in another five hours. If oxygen is administered to the exposed person, as happens in emergency treatment, the COHb concentration drops more quickly. Once exposed, the body compensates for the reduced bloodborne oxygen by increasing cardiac output, thereby increasing blood flow to specific oxygen-demanding organs such as the brain and heart. This ability may be limited by preexisting heart or lung diseases that inhibit increased cardiac output.

The altitude of this lake is 3,500 feet. Altitude effects the toxicity of CO. With 50 ppm CO in the air, the COHb level in the blood is approximately 1% higher at an altitude of 4,000 feet than at sea level. This occurs because the partial pressure of oxygen (the gas pressure causing the oxygen to pass into the blood) at higher altitudes is less than the partial pressure of CO. Furthermore, the effects of CO poisoning at higher altitudes are more pronounced. For example, at an altitude of 14,000 feet, a 3% COHb level in the blood has the same effect as a 20% COHb at sea level.[7]

References

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Attachment 2
Evaluation Criteria

Although NIOSH typically focuses on occupational safety and health issues, the Institute is a public health agency, and cannot ignore the overlapping exposure concerns in this type of setting. Park Service and Aramark employees should be in a state of health typical of any industrial worker. Thus, occupational criteria for CO exposure are applicable to that group.
The general boating public, however, may range from infant to aged, be in various states of health and susceptibility, and be functioning at a higher rate of metabolism because of increased physical activity. The effects of CO are more pronounced in a shorter time if the person is physically active, very young, very old, or has preexisting health conditions such as lung or heart disease. Persons at extremes of age and persons with underlying health conditions may have marked symptoms and may suffer serious complications at lower levels of carboxyhemoglobin.[(1)] The occupational exposure limits noted below should not be used for interpreting general population exposures because they would not provide the same degree of protection they do for the healthy worker population.

Occupational Exposure Criteria. As a guide to the evaluation of the hazards posed by workplace exposures, NIOSH field staff employ environmental evaluation criteria for the assessment of a number of chemical and physical agents. These criteria are intended to suggest levels of exposure to which most workers may be exposed up to 10 hours per day, 40 hours per week for a working lifetime without experiencing adverse health effects. It is, however, important to note that not all workers will be protected from adverse health effects even though their exposures are maintained below these levels. A small percentage may experience adverse health effects because of individual susceptibility, or a pre-existing medical condition. In addition, some hazardous substances may act in combination with other workplace exposures, the general environment, or with medications or personal habits of the worker to produce health effects even if the occupational exposures are controlled at the level set by the criterion. These combined effects are often not considered in the evaluation criteria. Finally, evaluation criteria may change over the years as new information on the toxic effects of an agent become available.

The primary sources of environmental evaluation criteria for the workplace are: (1) NIOSH Recommended Exposure Limits (RELs),[(2)] (2) the American Conference of Governmental Industrial Hygienists' (ACGIH®) Threshold Limit Values (TLVs®), [(3)] (3) the legal requirements of the U.S. Department of Labor, Occupational Safety and Health Administration (OSHA) Permissible Exposure Limits (PELs),[(4)] and (4) the American Society of Heating, Refrigerating, and Air-ConditioningEngineers (ASHRAE) Standard for ventilation for acceptable indoor air quality.[(5)] Employers are encouraged to follow the more protective criterion listed.

A TWA exposure refers to the average airborne concentration of a substance during a normal 8-to-10-hour workday. Some substances have recommended short-term exposure limits (STEL) or ceiling values which are intended to supplement the TWA where there are recognized toxic effects from higher exposures over the short-term.

The NIOSH REL for CO is 35 ppm for an 8-hour TWA exposure, with a ceiling limit of 200 ppm which should never be exceeded.[6,7] The NIOSH REL of 35 ppm is designed to protect workers from health effects associated with COHb levels in excess of 5%.[1] NIOSH has established the immediately dangerous to life and health (IDLH) value for CO as 1,200 ppm.[8] An IDLH value is defined as a concentration at which an immediate or delayed threat to life exists or that would interfere with an individual's ability to escape unaided from a space.

The ACGIH recommends an eight-hour TWA TLV of 25 ppm based upon limiting shifts in COHb levels to less than 3.5%, thus minimizing adverse neurobehavioral changes such as headache, dizziness, etc, and to maintain cardiovascular exercise capacity.[9]

The OSHA PEL for CO is 50 ppm for an 8-hour TWA exposure.[10]

Health Criteria Relevant to the General Public.
The US EPA has promulgated a National Ambient Air Quality Standard (NAAQS) for CO. This standard requires that ambient air contain no more than 9 ppm CO for an 8-hour TWA, and 35 ppm for a one-hour average.[11] The NAAQs for CO was established to protect "the most sensitive members of the general population" by maintaining increases in carboxyhemoglobin to less than 2.1%.

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10. 29 CFR 1910.1000 Table Z-1: Limits for air contaminants. Code of Federal Regulations, Department of Labor, Chapter XVII - Occupational Safety and Health Administration.

11. US Environmental Protection Agency [1991]. Air quality criteria for carbon monoxide. Publication No. EPA-600/8-90/045F. Washington, D.C.

Attachment 3

Carbon Monoxide Testing Conducted by USNPS and ARAMARK Staff
August 25, 2000

CARBON MONOXIDE TESTING
August 25, 2000

At 1030 hours I met with Diane Maris, Gary Anderson (ARAMARK Concessions) and Brian O'Dea at Wahweap Marina in Page, Arizona. The purpose of this meeting was to measure Carbon Monoxide levels associated with the operation of generators on Stardust and similar constructed houseboats.

The device used for measuring the CO levels was the SafeTmate 400 portable gas monitor manufactured by the Gastech Corporation of Newark, California, (Ser#9306124). Gary Anderson calibrated this instrument and adjusted the ambient oxygen sensor to 20.9 percent.

Prevailing conditions at 1030 hours:

Temperature	92
Dew Point	56
Humidity	49%
Barometric Pressure	30.26 and rising
Prevailing Wind	N/E @ *5 MPH*
Lake Elevation	3680 feet above Sea Level

A total of three houseboats in the sixty-five foot length class were tested in their slips at Wahweap Marina, a Lakeview and two Stardust Cruiser. These vessels were moored bow first in to the slips and chosen because of the prevailing wind blowing into and away from their stem decks. The generators on these vessels were not tested under a load, but at idle speeds (less than 800 RPMs) with the generators operating for less than 10-minutes.

Vessel *1 (Joint-Ownership vessel, twenty owners)*
1993 Lakeview Houseboat, 64-feet in length with a sixteen foot beam with the generator exhausting through the center area of the transom under the swim deck..

The vessel's bow was quartered into the wind *(bow facing east and the prevailing wind was from the N/E at 5 MPH).* A vessel in the neighboring (northern) slip blocked the majority of wind from reaching the testing area on stem deck.

Generator was turned on at 1110 hours.
1113 hours, CO reading eight feet behind the vessel's swim platform ... 30 PPM
1116 hours, CO reading eight feet behind the vessel's swim platform ... 1000 PPM
1120 hours, CO reading on the vessel's swim platform ... 800 PPM
1121 hours, CO reading at the swim deck's water ... 2000+ PPM

During the first test we realized that the SafeTmate 400 meter would not be effective in conducting these tests. This meter can only register carbon monoxide levels to a limit of 2000 PPM and this vessel surpassed that range. Also, within five minutes of conducting the test on the first vessels Ranger O'Dea and myself started feeling symptoms of CO Poisoning, headache, mild nausea and weakness.

Vessel 2 *(Single owner)*

1988 Stardust Cruiser Houseboat, 65-feet in length with a sixteen foot beam with the generator exhausting through the center area of the transom under the swim deck.

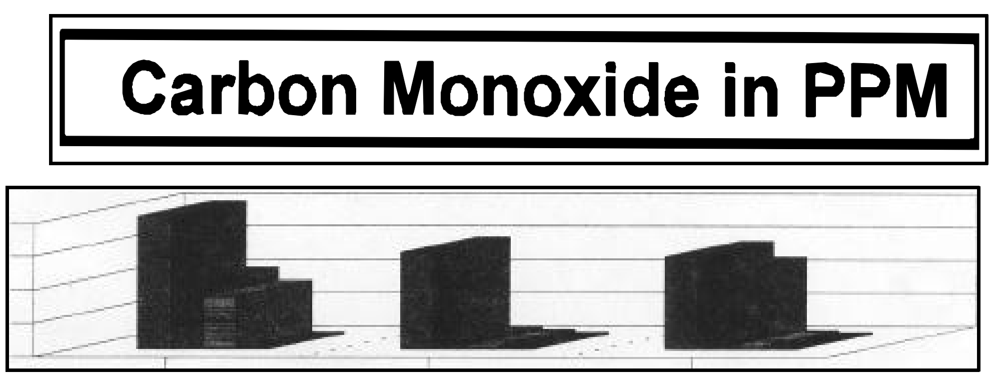
The vessel's stem was quartered into the wind *(bow facing west and the prevailing wind from the N/E at 5 MPH).* There was no structures in the area that blocked or altered the wind from reaching the testing area on stem deck.

Generator was turned on at 1150 hours.
1153 hours, CO reading eight feet behind the vessel's swim platform ...
1166 hours CO reading on the vessel's swim platform ... 100 PPM
1120 hours, CO reading on the vessel's stem deck ... 70 PPM
1121 hours, CO reading at the swim deck's water surface ... 1451 PPM

Vessel 3 .*(Joint-Ownership vessel, less than twenty owners)* 1998 Stardust Cruiser Houseboat, 67-feet in length with a sixteen foot beam with the generator exhausting

The vessel's stem was quartered into the wind *(bow facing west and the prevailing windfrom the N/E at 5* MPH). There was no structures in the area that blocked or altered the wind from reaching the testing area on stem deck.

Generator was turned on at 1230 hours.
1235 hours, CO reading on the.vessel's swim platform ... 1156 PPM
1238 hours, CO reading on the vessel's stem deck ... 60 PPM
1240 hours, CO reading at the swim deck's water surface ... 1393 PPM



Water Surface Behind Swim Platform
Standing on Swim Deck
Standing on Stem Deck
OSHA Hazardous Limit for Closed Area

Future testing should include hull displacement variables, *(i.e.)* vessel loading and beaching positions that would result in bow high and stem down positions. Future testing should also be done with the generators operating under a load (approx. at 75% of their operating speed) and for a period of at least 15-minutes.

It is a known fact that the gasoline engines used in marine applications produced higher carbon monoxide levels than standard gasoline engines and vessels on Lake Powell may actually be producing even higher CO levels than similar vessels on other lakes. Carbon monoxide levels are directly related to engine performance, the lack of maintenance, gasoline octane and altitude are some of the factors that result in gasoline engines producing increased levels of carbon monoxide. A high percentage of privately owned houseboat on Lake Powell are "Joint Ownership" with an average of twenty owners per vessel. These vessels are continuously operated during the summer boating season and rarely if ever receive maintenance during that time. As an example, generator manufacturers require minium servicing every one-hundred hours of operation, the majority of these houseboat will put that much time on their generator every two weeks. Worn engines, poor maintenance, Lake Powell's high altitude and the low octane fuels are potentiating carbon monoxide levels.